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USE OF STS SUBSYSTEMS AND COMPONENTS FOR MMSE

EXECUTIVE SUMMARY

DECEMBER 1975 Volume 1

Space Division
Rockwell International

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FOREWORD

Multiuse Mission Support Equipment (MMSE) is that flight/ground equipment for the Shuttle era which is used in conjunction with more than one mission payload. It is expected to be used repeatedly with appropriate refurbishment between uses.

This study provides NASA with initial verification of STS subsystems applicability to MMSE, along with the cost savings potential and programmatic data needed for further program planning decisions.

Some 70 MMSE requirements were found to be potentially satisfied by STS equipment, and six items of particular interest were chosen for special emphasis. All were found to be feasible and beneficial to NASA. Program cost savings through their use is estimated to be substantial; approximately $200 million can be saved over 10 years by use of STS subsystems and components to fulfill presently identified MMSE requirements. This saving becomes more than $400 million by implementing the STS multiple-launch capability for Thor-Delta payloads with utilization of MMSE payload spin-up mechanisms.

Considering the potential savings involved, it is strongly recommended that the study be continued to identify additional MMSE requirements and hardware. Detailed definition studies are recommended for FY '76 in support of needed procurements in FY '77.

The work described in this final report was performed under a $75,000 contract, NAS9-14598, for NASA Johnson Space Center. The NASA Technical Monitor (COR) was L. J. Nado and the Rockwell Study Manager was J. O. Matzenauer. Any questions concerning the material presented can be addressed to either of these individuals.

The contract required mid-term and final briefings and reports. The final briefing presentation is identified as SD 75-SA-0182 and the final detailed technical report as SD 75-SA-0181, Volume 2.

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INTRODUCTION AND BACKGROUND

Payload support and interface equipment can be categorized as "mission-unique" or as "multi-use". The former is utilized only very infrequently or for only one payload, whereas the latter is used more frequently and by more than one payload or payload discipline. Thus, multi-use mission support equipment (MMSE) can be in the form of removable, reusable equipment to be installed in the Shuttle Orbiter, as mission payloads demand. This support equipment may provide an intricate interface with Orbiter subsystems in many cases. It is a logical assumption that presently developed Orbiter subsystems or components might also be utilized in the support equipment to avoid developing more expensive new equipment. A considerable detailed knowledge of currently developed vehicle (Orbiter) systems is required to be able to apply that equipment effectively to the MMSE role.

OBJECTIVES

The objective of this study was to identify STS or other (principally, Orbiter) equipment that might be utilized to save funds in the additional application as MMSE, either as a part or as a complete MMSE kit, and for either airborne (ASE) or ground (GSE) support categories. Initial concept and programmatic planning data was also to be provided along with recommendations for future funded effort, particularly for FY '77 hardware starts. Figure 1 depicts these objectives.

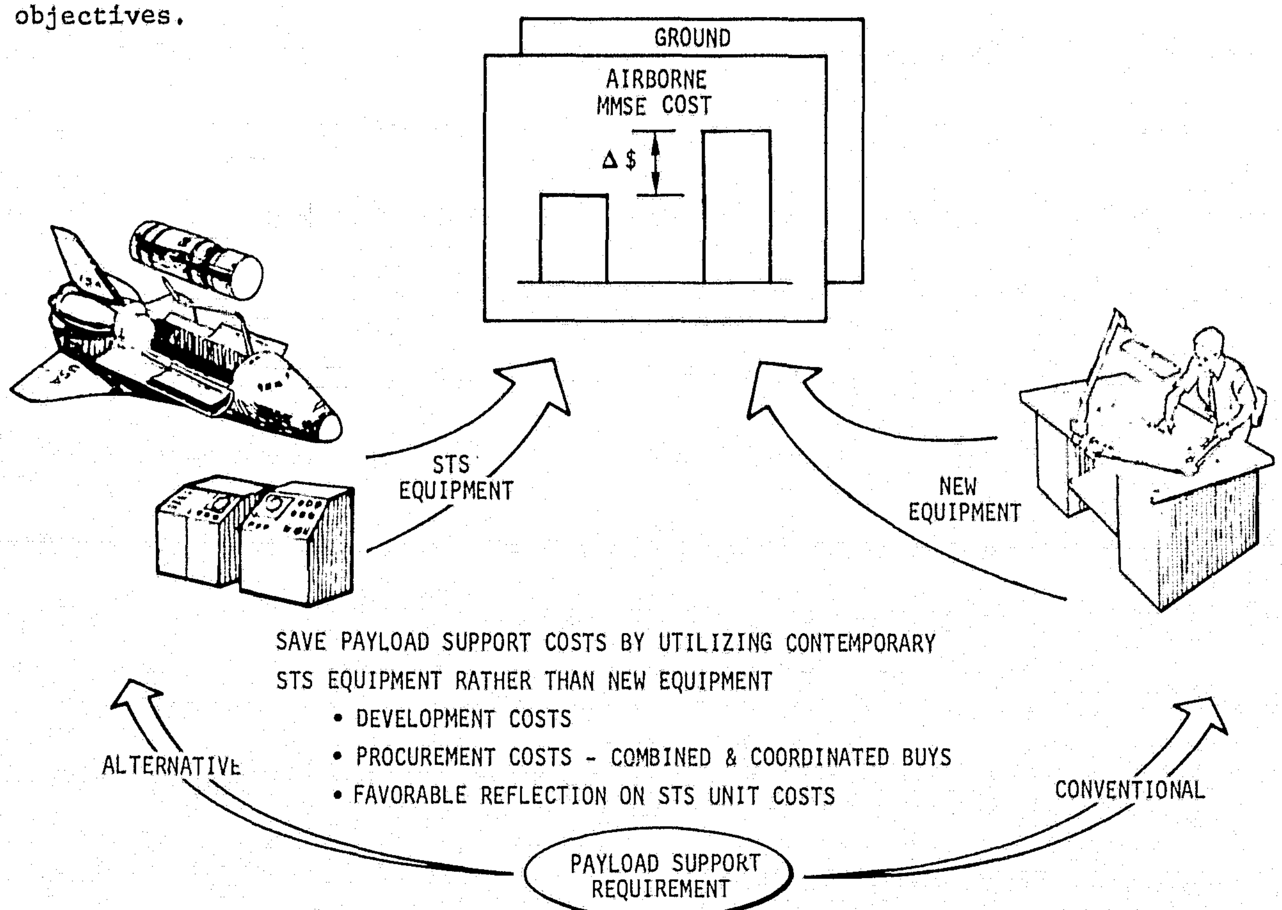


Figure 1. Objectives

APPROACH AND SCOPE

The study was funded at $75K for an 8-month period. The approach is illustrated in Figure 2.

Previous MMSE studies were used as a basis for MMSE requirements and these requirements were augmented by Rockwell's own experience. Characteristics of Orbiter subsystems/equipment were compared to the requirements and the most appropriate apparent matches, some 70 items, were described in more detail on individual "concept data sheets". These potential concepts were then subjected to successive screenings, Figure 3, utilizing engineering judgement to select the best items from practical, useful, and cost-effective standpoints.

In a few cases the items did not fit a strict definition of the category of "STS equipment" but were carried along as MMSE concepts because of their important interfaces (example: payload-Orbiter electric cabling).

Six items were selected with the concurrence of the COR to be given "special emphasis." These became the principle efforts of the study. Within the limiting constraints of the funding available, these six items were analyzed to provide conceptual design, trade issues results, programmatic planning and economic data, unresolved issues, and remaining and recommended future effort. The result has been the identification of promising STS MMSE items and the need and timing of future effort.

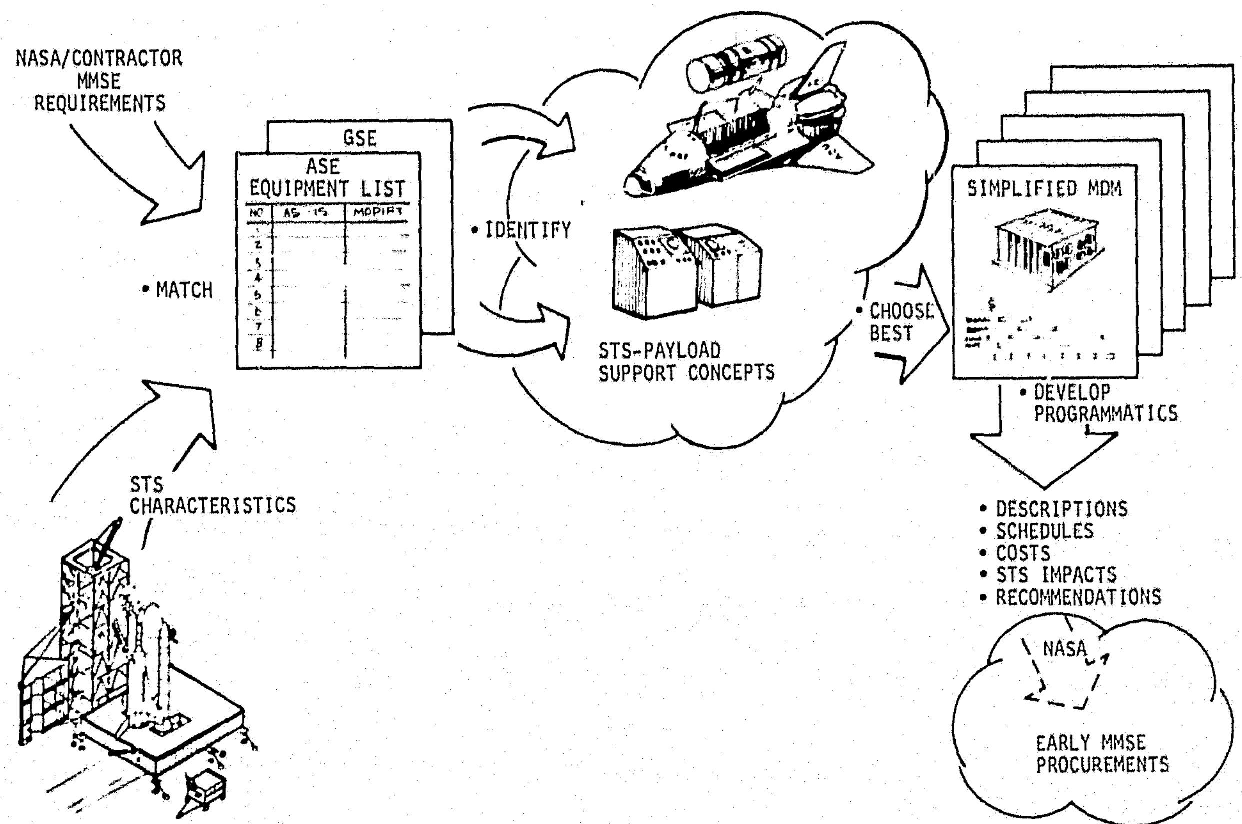


Figure 2. Study Scope

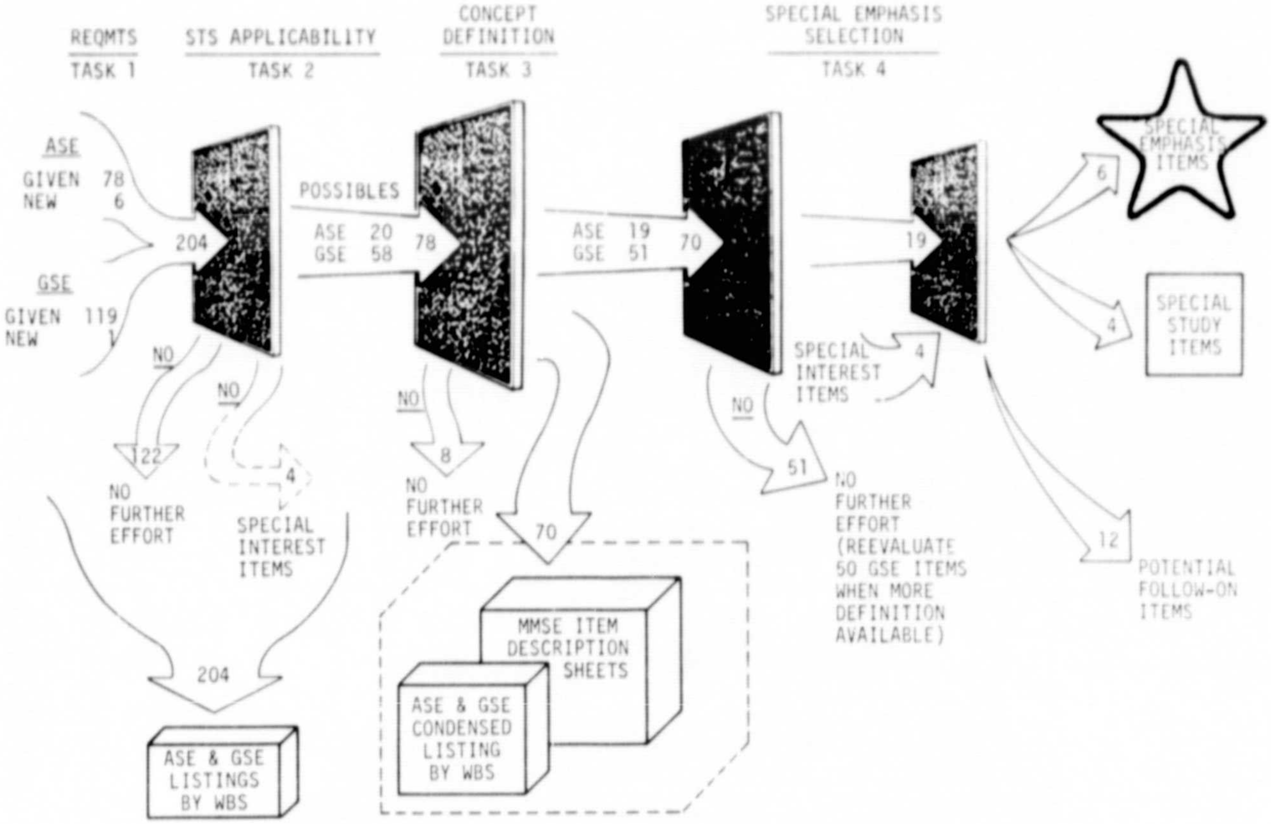


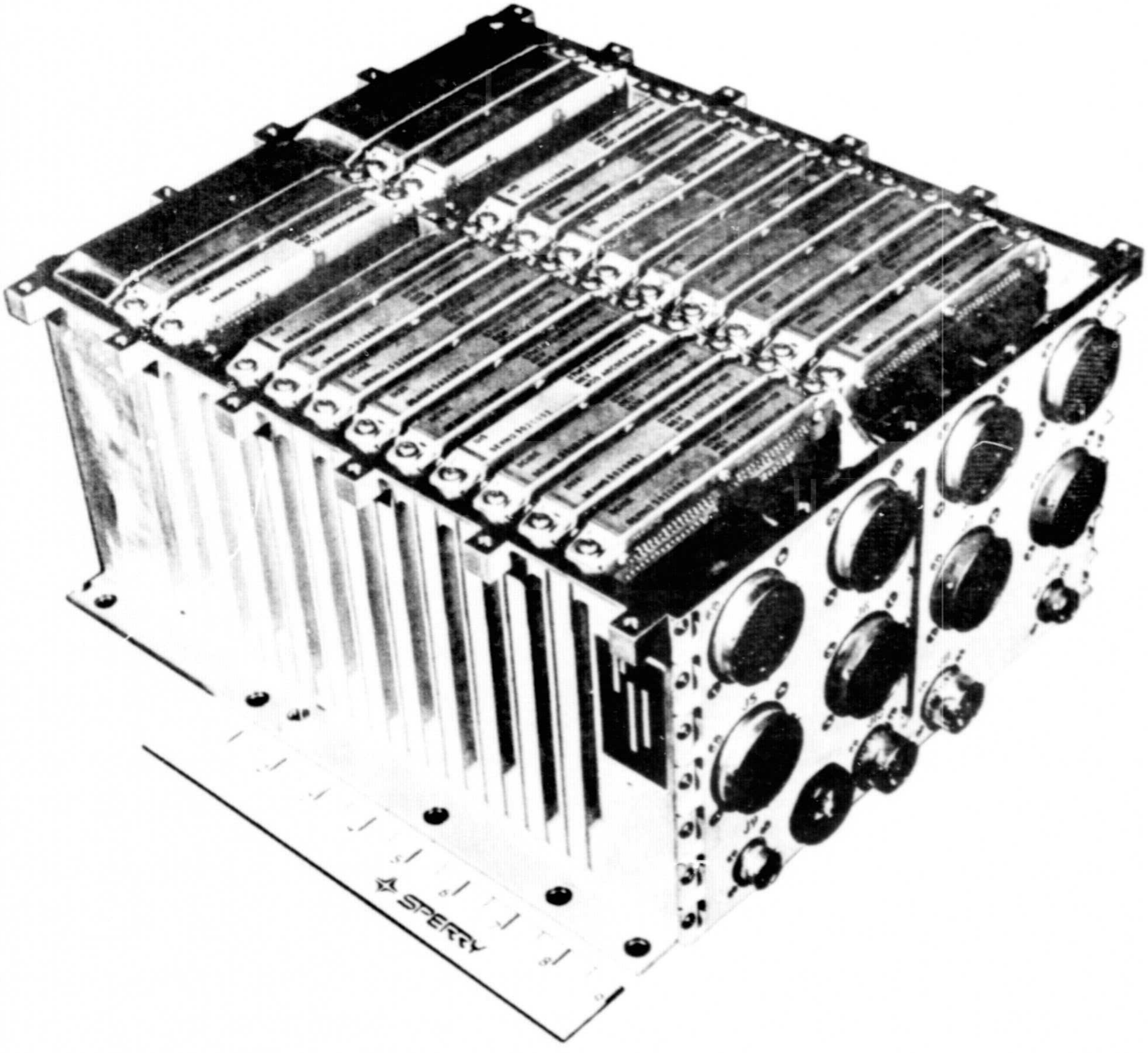
Figure 3. Disposition of Original Requirements

RESULTS

A large mass of data on potential use of STS subsystems/components for MMSE is contained in the Technical Report, SD 75-SA-0181, Volume 2. The following material will summarize results of the analysis of the six Special Emphasis items which are the principal output of the study.

1. Payload Version of Orbiter Multiplexer - Demultiplexer (PMDM)

The Orbiter MDM is illustrated in Figure 4. Being of modular, fully redundant construction, the individual input-output modules can be utilized as needed, as seen in Figure 4. Use of a simplified payload version of the Orbiter MDM (PMDM) to be mounted on the payload (or pallet) would enable a simple data bus interface with another PMDM (or an existing Orbiter MDM) in the Orbiter Payload Station (PS). This would provide the advantage of greatly reducing the long cable runs and buffering/amplifying electronics that would otherwise be required between the payload and the Orbiter. The long hardwire runs bring attendant problems in design, installation, and operation such as noise problems, calibration, integration uncertainties, EMI, interface buffer/driver hardware, etc.; Figure 5.



ORBITER MDM

CHARACTERISTICS

- 1 MBPS DATA BUS INTERFACE
- 30K WORDS PER SEC
  (16 BITS DATA PER WORD)
- BUILT-IN TEST
- FLEXIBLE INPUT-OUTPUT MAKEUP
- UNIVERSAL MODULE LOCATION SYSTEM

MAXIMUM DATA CAPACITY (PER SIGNAL TYPE)

TYPE	INPUT	OUTPUT
DC ANALOG (DIFF	256	256
DC ANALOG (SE)	512	N/A
DISCRETE (28V/5V)	768	768
SERIAL I/O	64	64

SIZE	330 X 254 X 178MM (13 X 10 X 7 IN.)
WEIGHT	16.6 KG (36.7 LB)
POWER	34 - 82 WATTS

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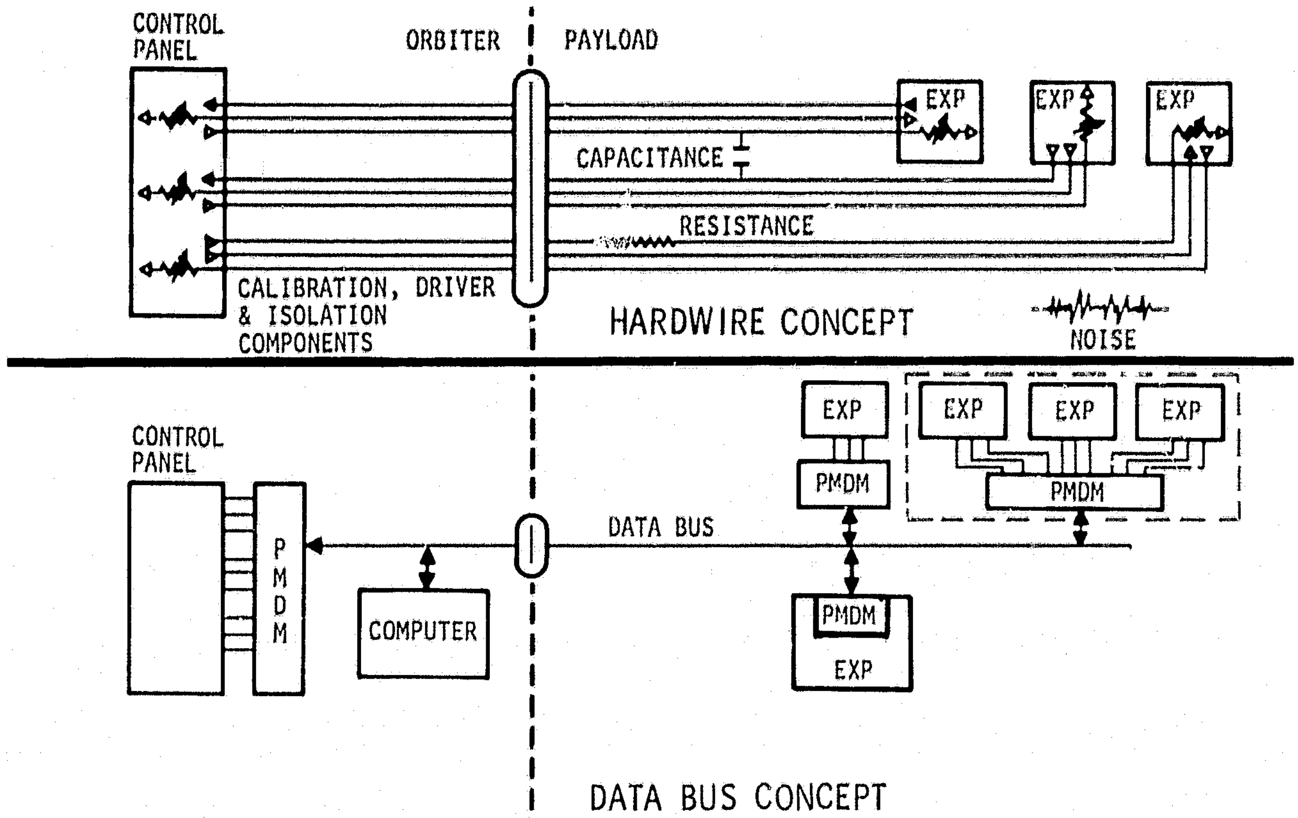
Figure 4. Orbiter Multiplexer - Demultiplexer (MDM)



ELIMINATES/REDUCES

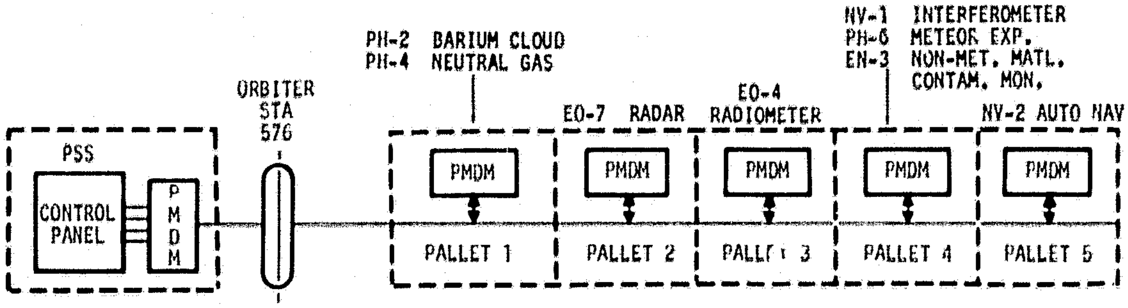
- NOISE PROBLEMS
- INTEGRATION PROBLEMS
- CALIBRATION, DRIVE, ISOLATION & INSTALLATION HARDWARE

Figure 5. Comparison of Hardwire and Data Bus Concepts

These uncertainties with long, large analog cables are the very reason that the MDM concept was chosen for Orbiter. Analysis of typical payload data, signal types and numbers such as seen in Figure 6 shows that considerably less than the full Orbiter MDM signal-handling capability is required. Several reduced-capability options, including the deletion of the 100% redundancy contained in the Orbiter MDM, were considered, see Figure 7.

The "1/2 - size" version with 8 input-output modules (IOM's) is the apparent choice.

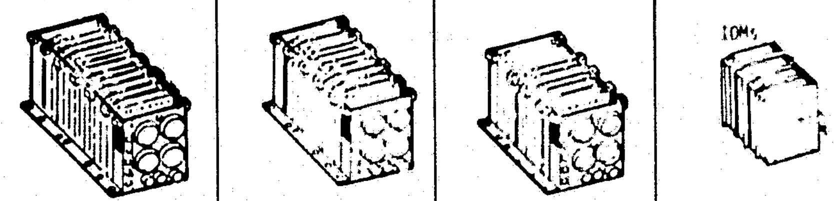
Assuming that a demonstration flight is highly desirable during the early Orbiter flight test program in order to demonstrate usefulness to payload users, the schedule of Figure 8 can be constructed to indicate the preceding phases of procurement. Using "normal" estimates of phasing this results in a need for a refined definition study in the first half of calendar year 1976. It is considered important to provide sufficient time for studying payload requirements and optimizing the design of the PMDM prior to procurement of hardware. The actual production does not need to be started until early 1978 (mid-FY '78) because of its relatively simple nature in terms of the prior Orbiter MDM hardware. As noted, the PMDM sequential procurement does not impact the hardware for Shuttle.



	PSS		PALLET 1	PALLET 2	PALLET 3	PALLET 4	PALLET 5
DISCRETE INPUTS	158		26	1	1	21	21
DISCRETE OUTPUTS	37		39	20	22	44	48
ANALOG INPUTS			12	3	12	37	6
ANALOG OUTPUTS	* 25						
DIGITAL INPUTS			3	-	-	1	5
DIGITAL OUTPUTS	* 25						

* DRIVE SIGNALS FOR PANEL INDICATORS COULD BE DIGITAL OR ANALOG

Figure 6. Example Requirements (ATL Pallet)

	SIMPLEX MDM A	SIMPLEX MDM B	SIMPLEX MDM C	MODULAR
				IOMs
CORE (4 MODULES)	SIMPLEX	SIMPLEX	SIMPLEX	SIMPLEX
IOMs	8	6	4	AS REQUIRED
UNIT COST NR	280K	SAME	SAME	NONE ●
UNIT COST R	60K + PROG MGMT	51K + PROG MGMT	42K + PROG MGMT	4.5K EA [illegible]
MAX CAPACITY DISCRETE I/O	384	288	192	48 PER IOM
ANALOG SINGLE ENDED OR DIFFERENTIAL INPUT	256	192	128	64 PER IOM
ANALOG DIFFERENTIAL OUTPUT	128	96	64	32 PER IOM
SERIAL I/O	32	24	16	4 PER IOM
SIZE (APPROX)	330 x 127 x 178MM (13 x 5 x 7 IN.)	279 x 127 x 178MM (11 x 5 x 7 IN.)	229 x 127 x 178MM (9 x 5 x 7 IN.)	127 x 147 x [illegible]MM (5 x 5.8 x [illegible] IN.)
WEIGHT (APPROX) (ALL IOM'S INSTALLED)	8.3 KG (18.4 LB)	7.1 KG (15.7 LB)	5.9KG (13 LB)	0.6 KG (1.3 LB)

● INCREASES EXPMT INTEGRATION COST. SPECIAL MODULES MAY BE DEVELOPED AT ≈ 25K EACH

Figure 7. Payload MDM Options

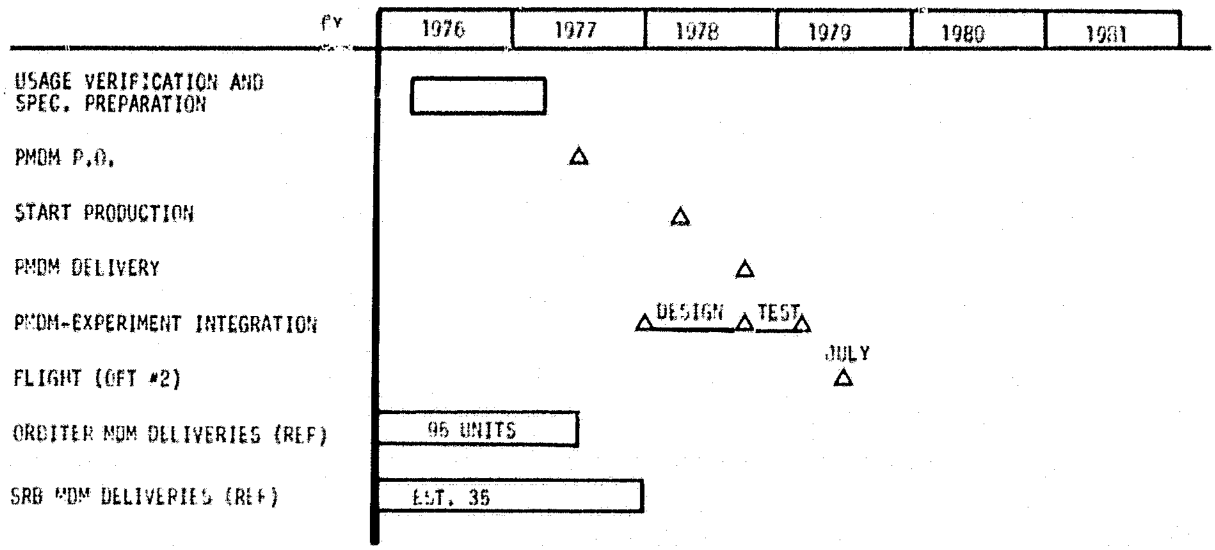


Figure 8. Preliminary Implementation Schedule - PMDM

It is concluded that the PMDM is a desirable device for reasons that parallel those resulting in its choice for Orbiter subsystems data bus interfacing. The concept is feasible, flexible, and cost-effective as an alternative to the present hardwiring concept and would favorably impact payload development and Orbiter turnaround operations.

2. Payload Version of Orbiter Star Tracker

The Orbiter star tracker (OST), Figure 9, was investigated for adaptation/modification as a payload pointing sensor. With its associated Orbiter interface and support electronics, it was believed that this use might be advantageous relative to other proposed or apparent tracker options.

The Orbiter by itself is inherently capable of providing coarse orientation for payloads or experiments mounted on pallets, reference Figure 10, Sketch A. Most of the pointing uncertainty is due to thermal and structural deflection of the Orbiter between the forward-mounted nav base and the aft-mounted in-bay experiments. Another mode, "strapdown", Sketch B, employs a payload-mounted sensor to "drive" the Orbiter stability control system and could result in pointing the payload within about 0.1 degree, a 20-fold improvement over Sketch A. For even finer payload/experiment pointing, Sketch C indicates a payload-mounted gimbaled platform with its own sensors and platform stabilizing means.

The pointing accuracy requirements for various payloads vary between several thousand arc-seconds down to less than 1 arc-sec, Figure 11.

These requirements can be grouped as the 1 arc-second type, the 5 arc-sec type, and the 20-30 arc-sec type. The OST has been examined against these requirements and found to be adaptable with little change for the 20-30 arc-sec range. It may be used as a strap-down sensor to meet the 360 arc-sec

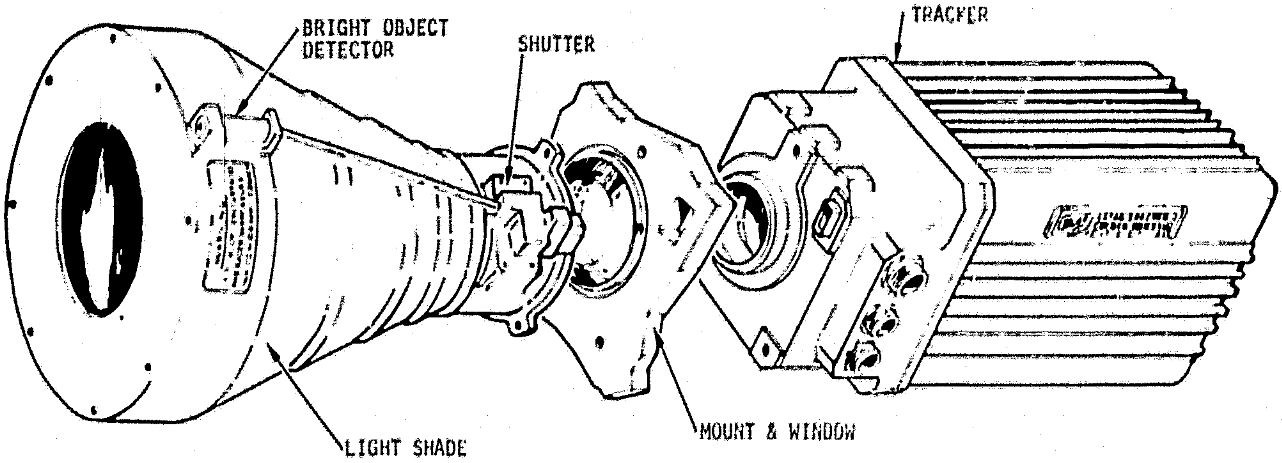


Figure 9. Orbiter Star Tracker and Light Shade Assembly

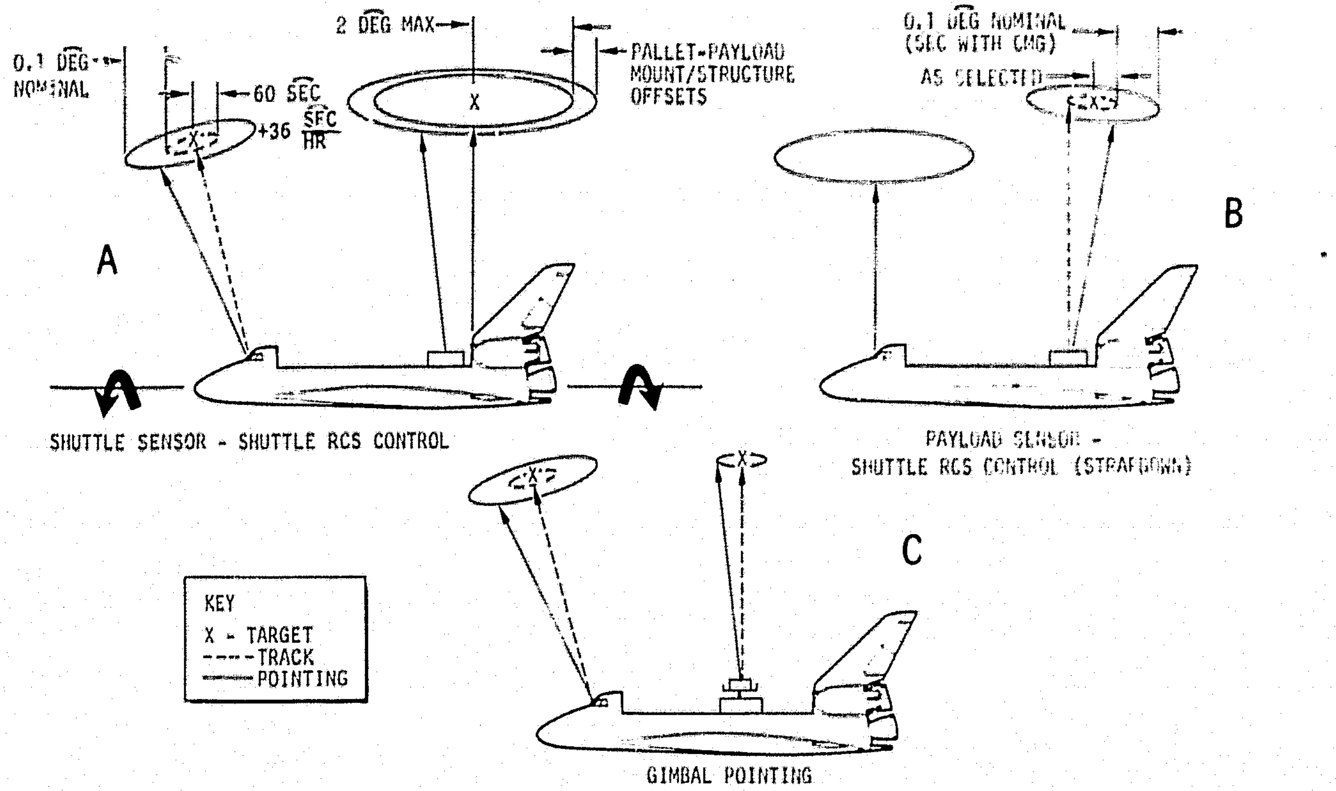


Figure 10. Basic Payload Pointing Concepts

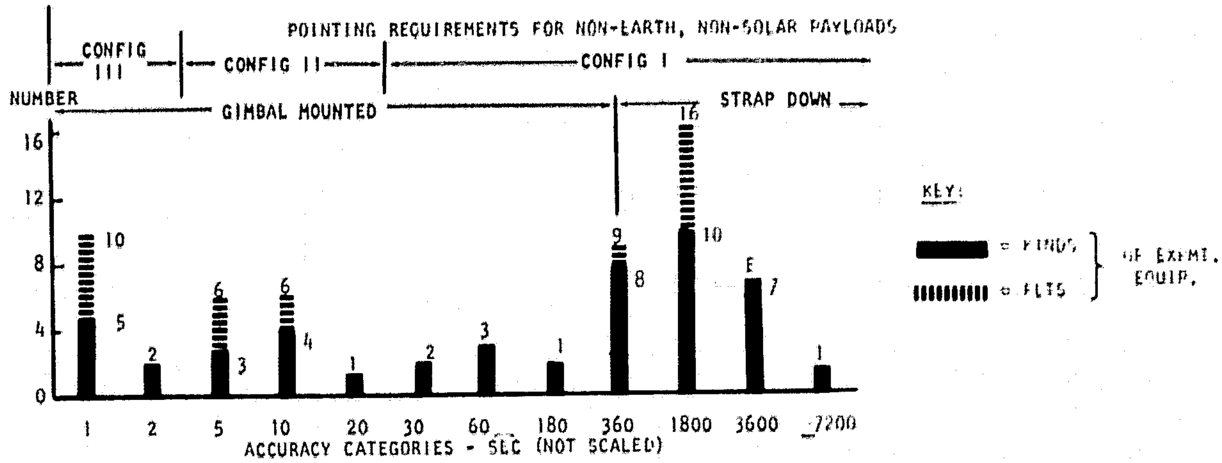


Figure 11. Pointing Accuracy Regimes

requirements and in a gimbaled or isolated platform mode between 20-30 arc-sec and 360 arc-sec. Additional internal/external electronics modifications are needed for the 5 arc-sec requirement, and very extensive modifications are needed for the 1 arc-sec capability. However, in spite of the modifications, the OST appears to be cost-effective and superior to the gimbaled ATM tracker recommended in a previous study, Table 1.

The OST has a major advantage in terms of its already Orbiter-compatible support electronics. With any other tracker for payload pointing use, considerable costs for such electronics development may be necessary.

Development schedule considerations are seen in Figure 12.

Table 1. Cost Data on Alternative Star Tracker Design Variations

STAR TRACKER CHARACTERISTICS	GIMBALED SKYLAB ATM	ORBITER STAR TRACKER CHANGE CATEGORY		
		I (BASIC)	II	III
FOV (DEG.)	+87°OG, +40°IG	10 x 10	6 x 6	1.25 x 1.25
STAR SENSITIVITY	MAG 3	MAG 3	MAG 6.3	MAG 9.3
ACCURACY	10-30 SEC	60 SEC	4-35 SEC	0.8-4 SEC
COST DATA				
NON-RECURRING				
REDESIGN & TEST (DIR)	$1,000K	--	$225K	$300K
PROG. MGMT. (40%)	400		90	120
TOTAL N-R	$1,400K	--	$315K	$420K
RECURRING (1 UNIT)				
PRODUCTION	$300K	$120K	$150K	$208K
PROG. MGMT.	90		45	62
TOTAL PROD.	$390K		$195K	$270K
OPERATIONS	SIGNIFICANT	NEGLIGIBLE	NEGLIGIBLE	NEGLIGIBLE

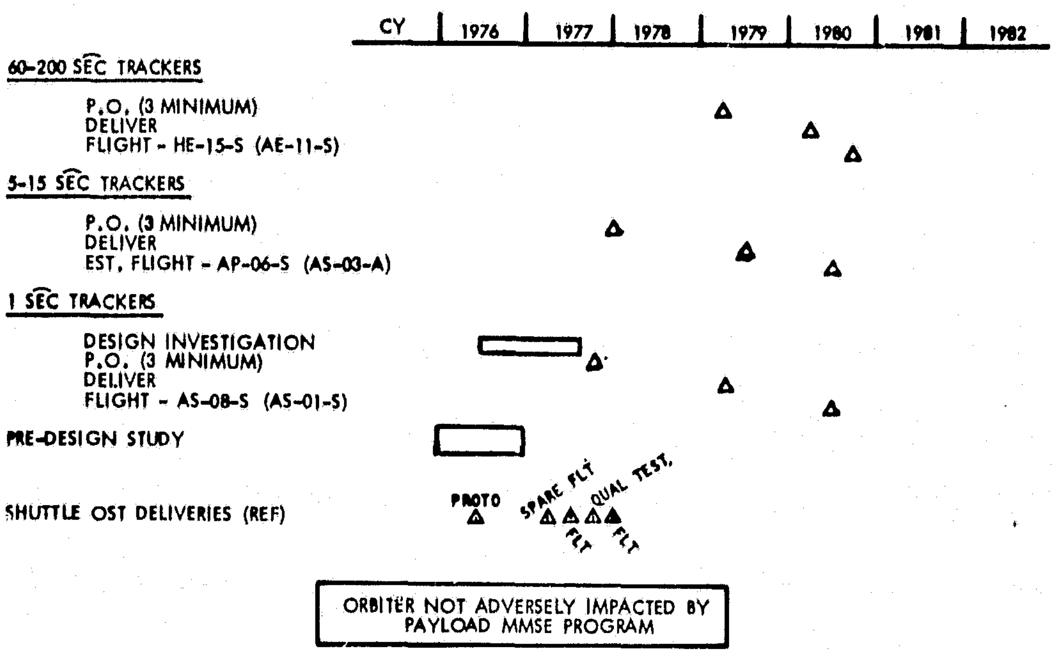


Figure 12. Estimated Schedule

Commitment to the availability of the modified Orbiter tracker (MOST) would be necessary in time for payload developers to plan for its implementation prior to use. A flight early in the Orbiter Flight Test (OFT) program would be highly desirable to verify function and accuracy capability. With "normal" procurement lead time, this would require that intensive design investigation of necessary OST modifications and integration would be needed as early as the first quarter of 1976 and procurement commitment by late FY '77.

It is concluded that MOST is technically and economically feasible for general application as a payload pointing sensor system and would be cost-effective relative to alternative suggested concepts in the previous MMSE study. However, before committing to this approach, the progress of JPL's low cost star tracker should be considered. The latter utilizes a charge coupled device as the primary sensor in place of the image dissector tube used in OST. The JPL approach, if successful, should show potential advantages in design simplicity and stability.

3. Payload Spin-up Mechanisms

Small spinning satellites have been included in plans for Orbiter Flight Test (OFT) payloads and in subsequent early operations plans. Since these are small, low-rpm spinners, a pre-deployment spin-up mechanism as an "end-effector" on the Orbiter's Remote Manipulator System (RMS), or manipulation arm, appeared to be feasible. This study was instigated to explore this concept for overall feasibility and mechanization.

An electric motor drive package was conceived for the RMS spin-up mechanism, Figure 13.

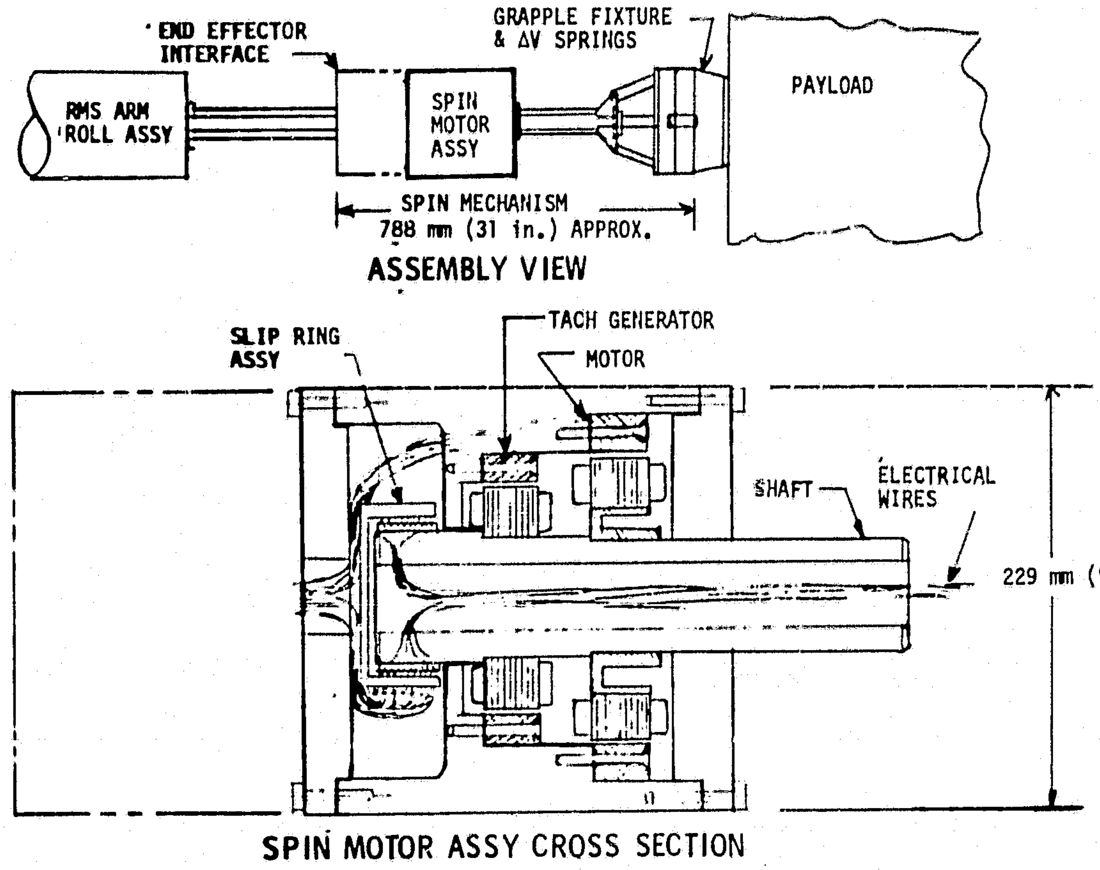


Figure 13. RMS Spin-up Mechanism Design Concept

Simplified dynamic analysis indicates that stability for the speed range up to 10 rpm should not be a problem. The development costs are modest and a straightforward development program is anticipated, Figure 14.

Normal lead times would dictate that more refined stability/stiffness analyses should be started in mid-1976 (at which time RMS stiffness data should be available) in order to lead to hardware availability in time for OFT Flight #3 in late 1979. It is also possible that stability augmentation could be provided to extend the useable limits of operation.

In addition, following interest expressed by NASA during the Mid-Term presentation, concepts have been investigated for in-bay spin-up of multiple spacecraft of the Thor-Delta size class as a company-funded effort. The in-bay spin-up mechanism for Thor-Delta class spacecraft is particularly significant in that it may constitute the best (or only) way of capturing these commercial-type missions with Shuttle. The objective was to determine if a feasible concept could be described that would be at least cost competitive with the basic Thor-Delta launch vehicle.

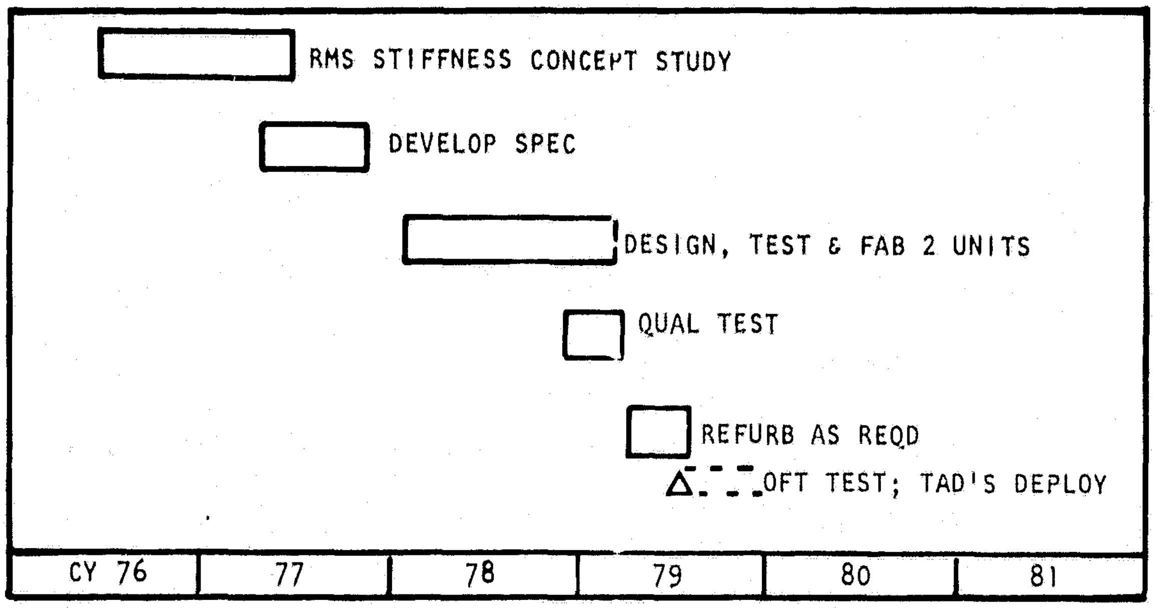


Figure 14. Program Implementation Schedules

The largest Thor-Delta payload fairing envelope is 2.2 meters (86 inches) diameter by 4.6 meters (182 inches) long. Two of these can be carried in the Orbiter bay stacked vertically (one over the other) to avoid a lateral c.g. problem if one payload cannot be launched. With another pair forward, four such payloads can be carried on a single flight, Figure 15.

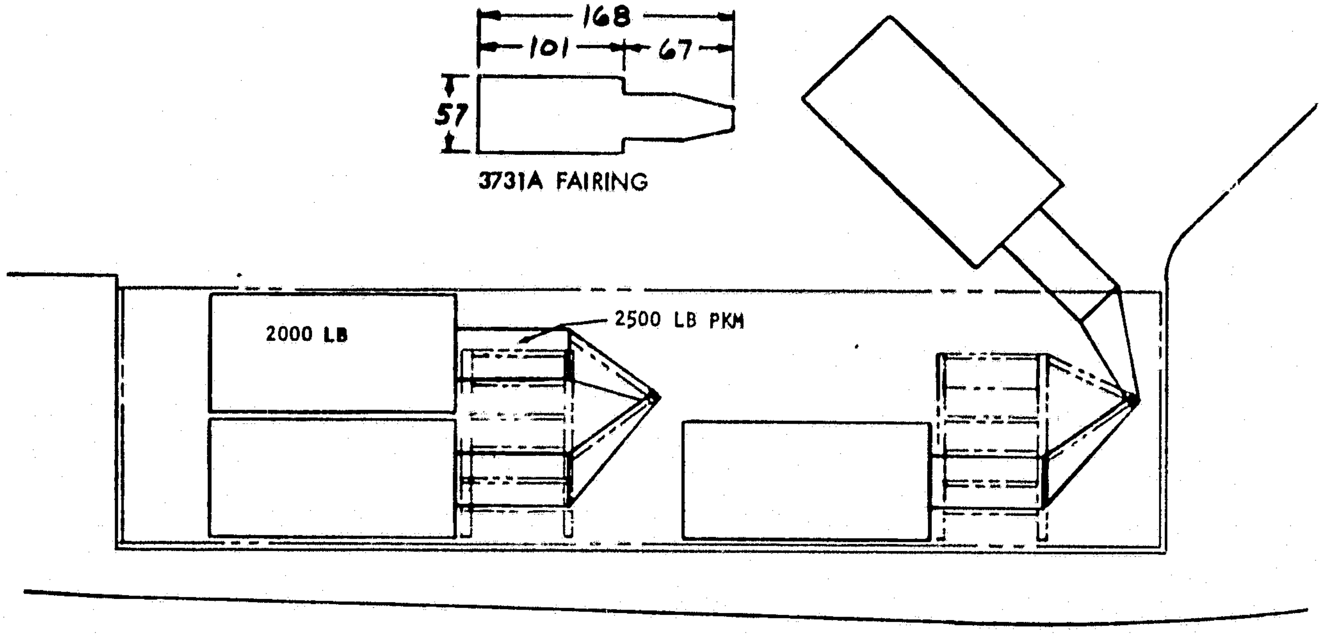
Each payload is sequentially elevated clear of the bay (and the other payloads) prior to spin-up. Thus, the concept of four (or more, depending on size) payloads deployed per Shuttle flight offers very attractive cost savings compared to four individual Thor-Delta launches; "four for the price of one."

A typical development schedule is seen in Figure 16.

Assuming the desirability of an early verification test of the mechanism during OFT, the concept would require procurement commitment in FY '77 and preliminary concept design refinement study in 1976.

4. Payload-Orbiter Fluid Lines

It is intuitively obvious that commonality (common usage) of fluid lines between payloads would be desirable to minimize lines development, storage, handling, and Orbiter turnaround time. This brief study was undertaken to obtain a preliminary indication of the degree to which this is possible or likely. It was found that certain compatible fluid groupings could use common lines (although line size determination in most cases must await further detailed definition of payload requirements). Typical payloads and the fluid servicing positions on Orbiter are seen in Figure 17.



- CLEARANCES BETWEEN PAYLOADS (4 IN.) & ORBITER ENVELOPE (2 IN.) NEEDS STUDY
- CLUSTERS OF FOUR SMALLER PAYLOADS POSSIBLE
- ATTITUDE ACCURACY PACKAGE NEEDED TO MEET DELTA'S CAPABILITY

Figure 15. Delta-Class Payload Capability

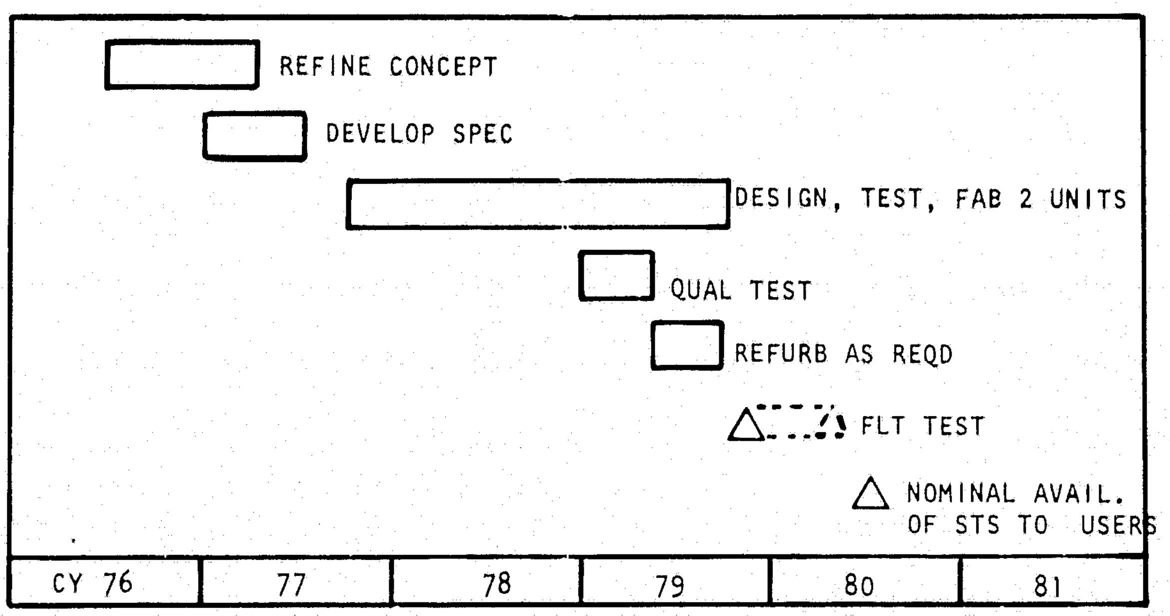
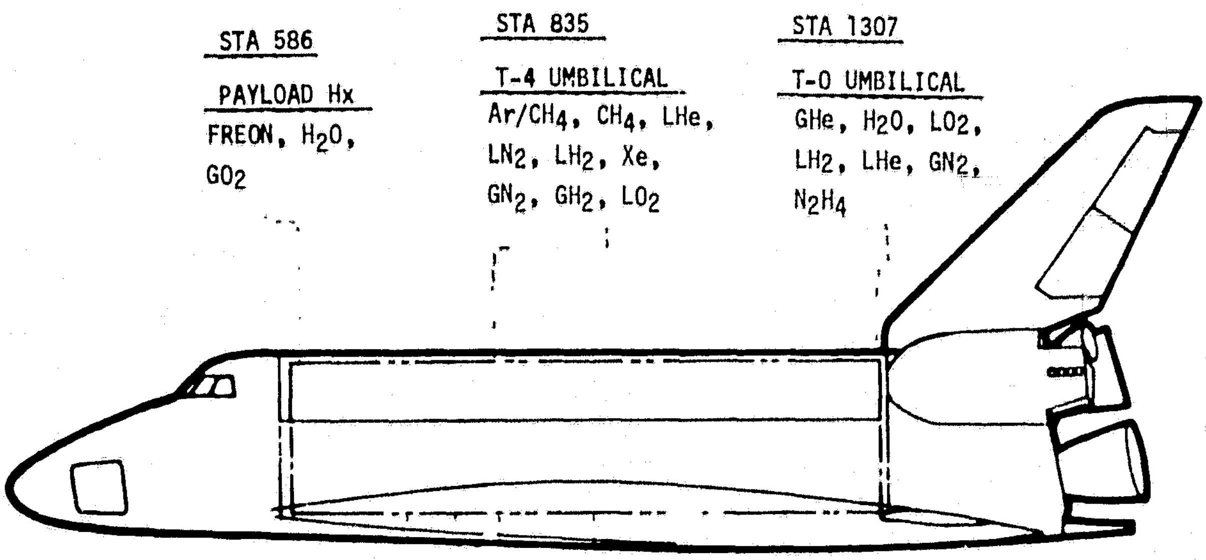


Figure 16. Program Implementation Schedules



PALLET			710/714	834	954	1074	1194
MODULE + PALLET	SM+2P/LM+1P SM+3P/LM+2P		768/776				
MODULE				835			
DoD-DMSP		720					
TUG							1246

Figure 17. Orbiter and Payload Interface Locations

A concept which calls for multiple lengths of a unit line length within each compatible fluid grouping appears feasible. Depending upon the concept for the joints (e.g., B-nuts vs. in-place brazing) and upon the tubing support concept, a set of unequal length lines rather than a short unit length may be more desirable. In any case, assuming that line sizes are reasonably compatible for the groupings, the total number of lines required to be developed and stocked can be reduced to less than half of those necessary without commonality.

Fortunately, time is available to gather payload data prior to actually developing the lines, as seen in Figure 18.

5. Payload-Orbiter Electric Lines

The objective of this task was to shed light on the ways and means to minimize the number of different electrical cables necessary for diverse payload accommodation.

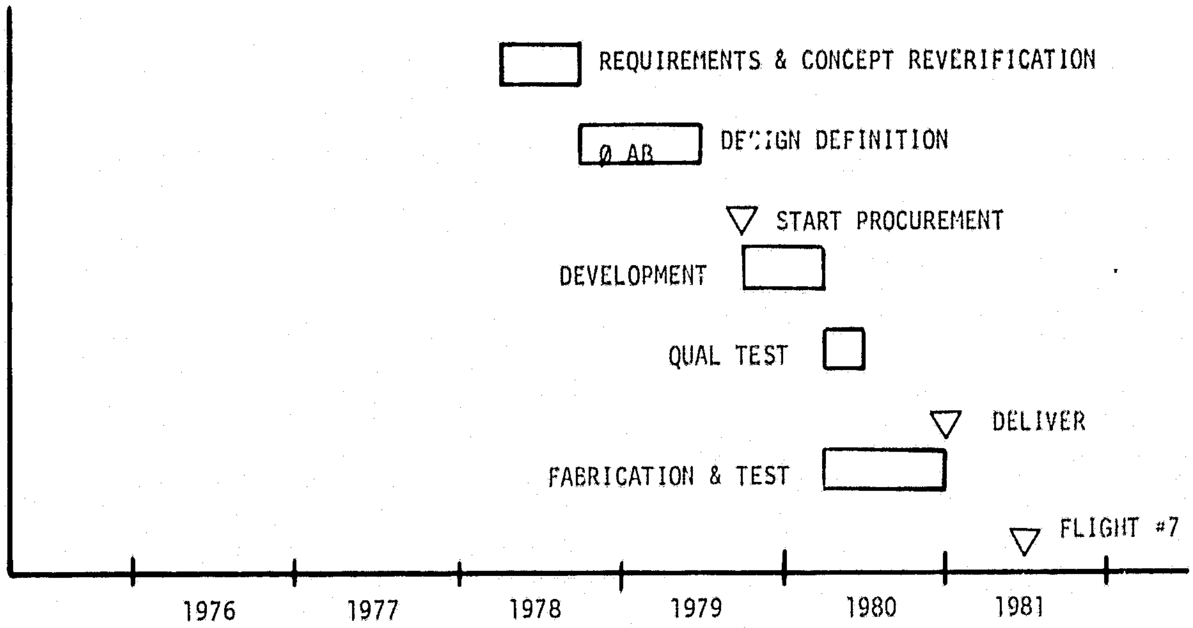


Figure 18. Schedule Considerations

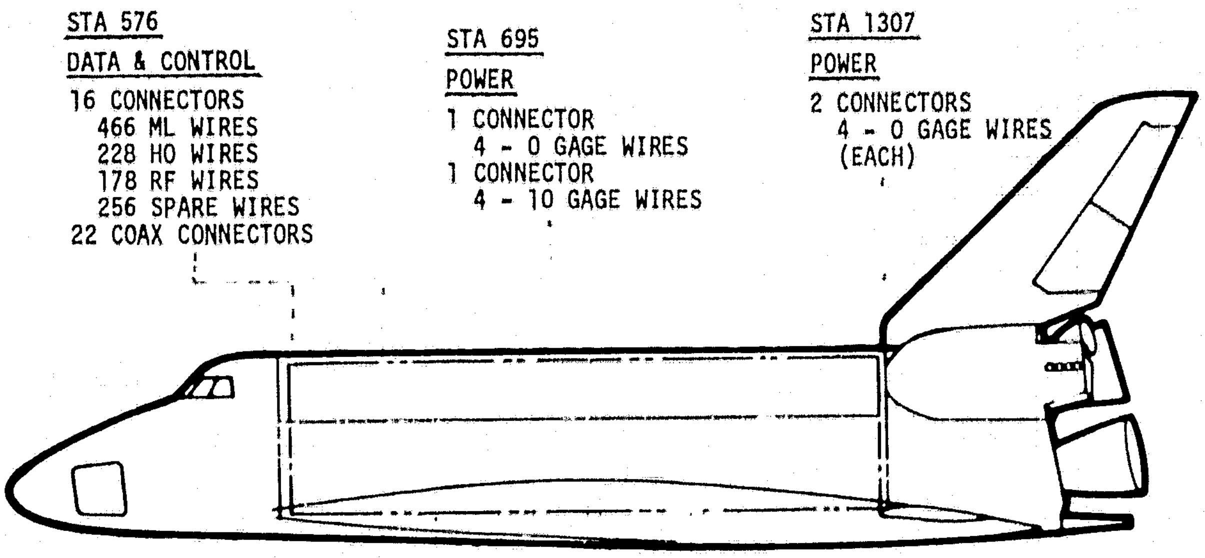
Orbiter electrical stations of significance and stations where planned payloads need electrical connection are seen in Figure 19.

Various options were investigated briefly to determine relative advantages and disadvantages. It was found to be particularly difficult to choose even a basic wire configuration concept because of the lack of detailed payload requirements and the need to do extensive layouts to evaluate installation factors such as real line lengths, actual physical support concepts, feasibility of excess length stowage, influence of lengths and routing on EMI, ground turn-around impacts, etc. Use of the PMDM concept described earlier would also impact heavily the optimum electric lines configuration. Two concepts were therefore indistinguishable in relative overall merit. One is using a set of different lengths of cables to accommodate a range of potential payload interface locations. The other concept calls for a permanently kitted set of cables with multiple outlets along the bay length. The latter will have more scar weight penalty in most cases but would be very advantageous for minimizing cost and turnaround operations between flights.

Additional detailed layout studies being conducted at Rockwell particularly for Spacelab configurations, under the basic Orbiter contract, should serve to explore these uncertainties. As with the fluid lines, there is, fortunately, time to develop data and concepts before hardware procurement is initiated in FY '79.

6. Multi-discipline Auxiliary Payload Power System

The objective of this study, conducted largely as a company-sponsored effort, was to determine if a multi-discipline system is needed and if so, how best to configure it.



PALLET		690/694	914	934	1054	1174	
MODULE + PALLET	SM+2P/LM+1P SM+3P/LM+2P	748/ 756					
MODULE		815					
DoD/IUS		833	951	1010	1128		
NASA/IUS		833	951	1010	1128		
DoD FREE FLYER		710	1069				
LCMS		1069					

Figure 19. Orbiter and Payload Interface Locations

Review of payload power requirements revealed that several payload disciplines need supplementary power inasmuch as Orbiter's 7 Kw average must be divided between the Spacelab/pallet subsystems and productive payload experiments. In previous studies, only space processing experiments were said to require supplementary power. Furthermore, the entire world of combined payloads can be another source of power demands. The missions identified and the power deficits are pictured in Figure 20.

It became clear early in the effort that there are distinct economies inherent in the approach of adopting not only Orbiter hardware or equipment but also in utilizing the inherent capabilities of the Orbiter subsystems to the degree compatible with their functions and operational constraints. First, Orbiter margins in the power system and attendant thermal control system were reviewed, but while some capabilities are available and could be used, this is not considered wise at this point of Orbiter development. Therefore, the major effort was placed on independent kits using fuel cells.

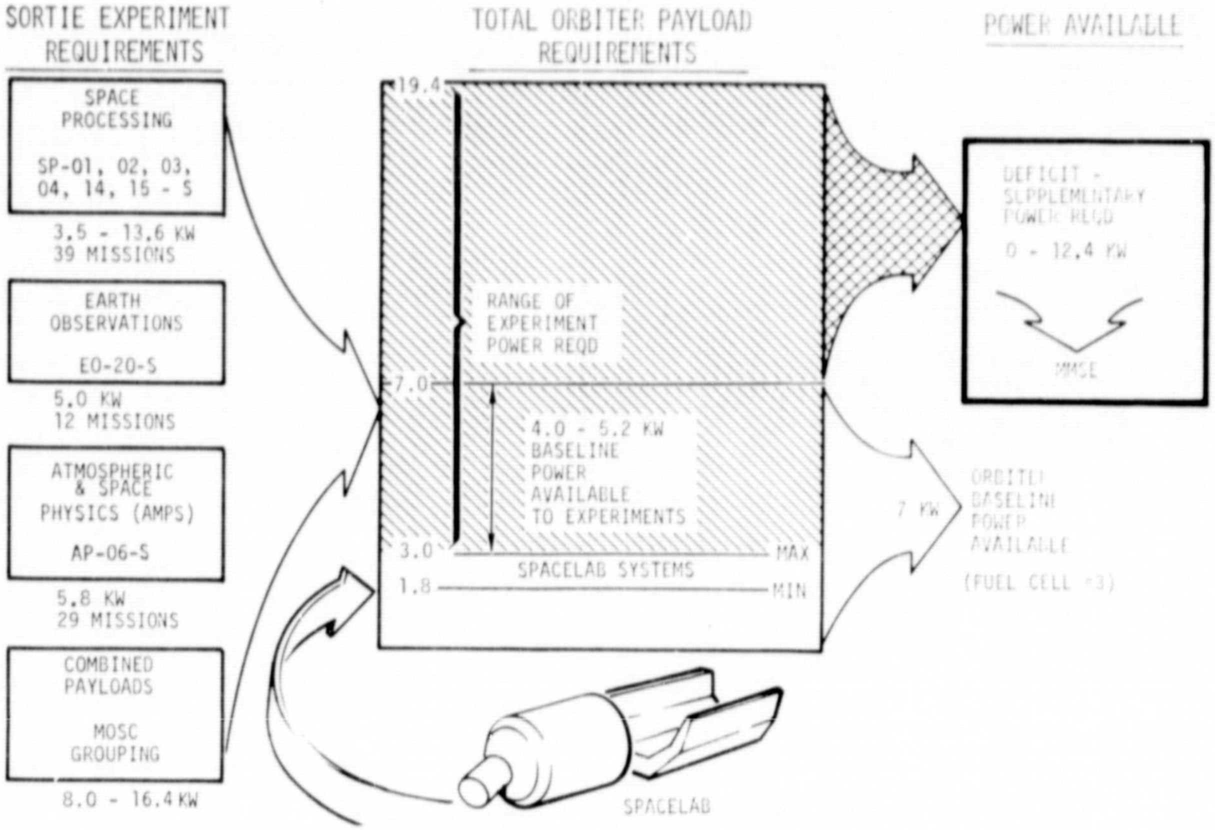


Figure 20. Auxiliary Integrated Power System

It was found that one or two extra fuel cells (as required) could be located intruding to a minor degree into the payload bay very close to the present location of the three Orbiter fuel cells. The cryogenics supply for these cells is the standard Orbiter extended mission kit tankage supply which can utilize up to 5 sets of tanks. Since these are already part of the Orbiter program, no expense for tankage development nor procurement is necessary. The radiator panels needed to reject the electric power heat are seen in Figure 21. They are standard Orbiter radiator panels and thus require no new development. The entire system is flexible for any payload requirement. A prime virtue is that very little of the Orbiter payload bay volume is taken up by the power kit, and no special pallet or support module is required for radiator support; radiators can be bolted to the top of any convenient Spacelab pallet to be utilized in the same mission.

Development costs and schedule considerations are seen in Figure 22. For the flight assumption of 1980, the high degree of Orbiter equipment utilization permits relatively late procurement phasing; procurement of hardware in FY '78 and conceptual refinement and design integration study in early 1976.

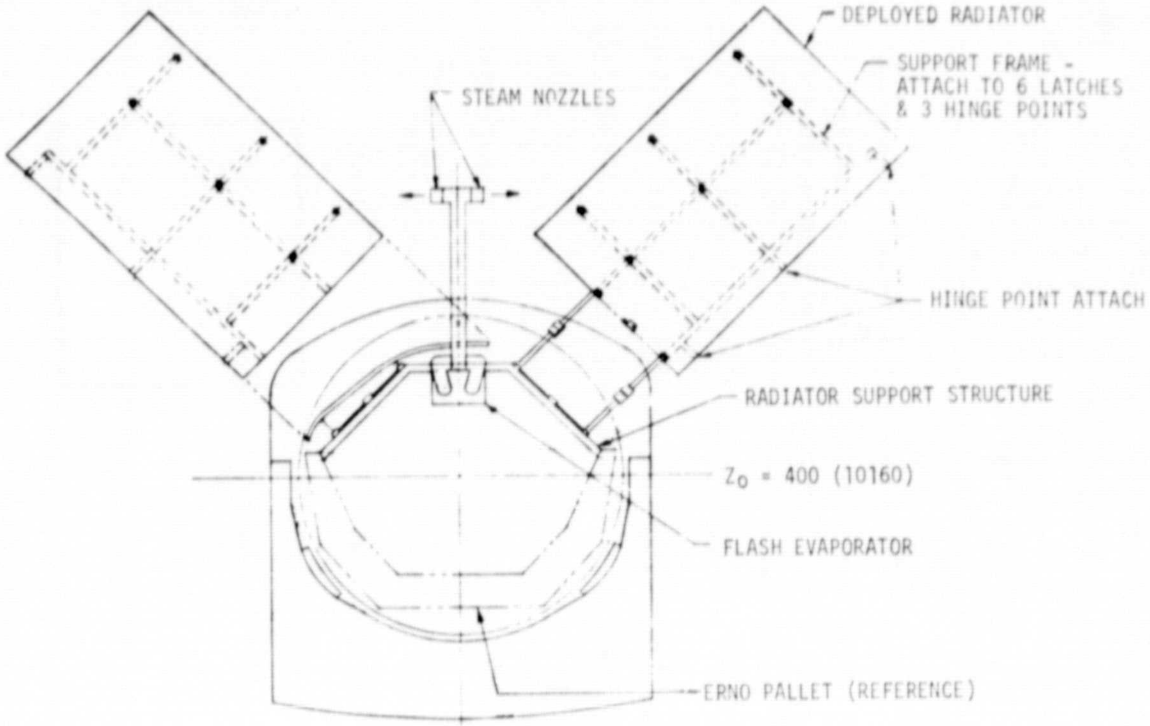


Figure 21. Deployable Radiator Kit Installation

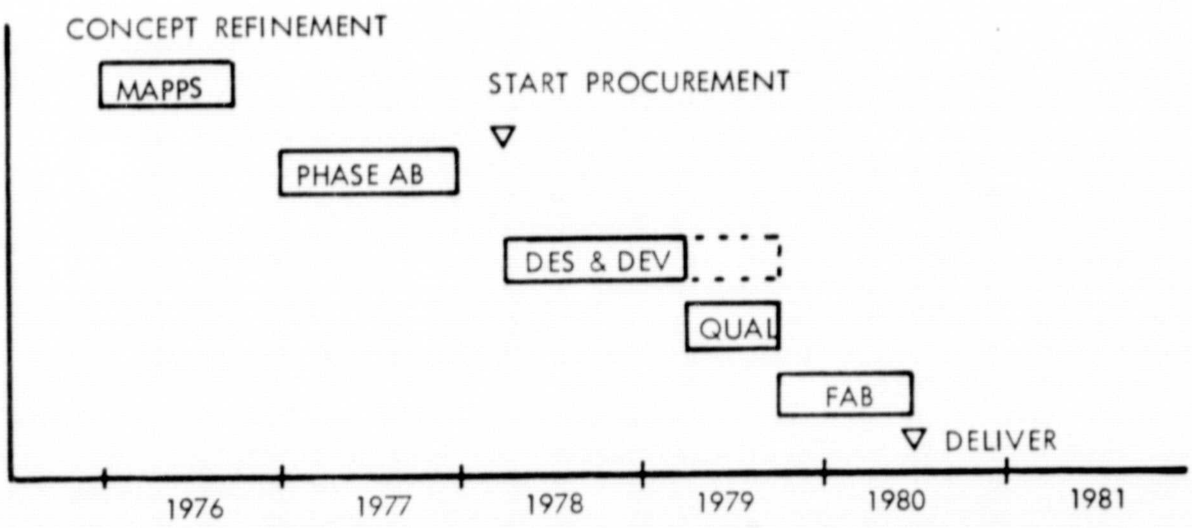


Figure 22. Schedule Considerations

The MAPPS concept appears unusually well suited for the identified · quirements and for the possible multiple payload requirements which are likel· o come. As a result of its design philosophy, MAPPS meets the desired objective of displacing practically no payloads in the bay, provides flexible energy as well as power level as a result of the use of standard cryo kit tanks, minimizes radiator costs by utilizing identical Orbiter parts and avoiding special support module developments or dedicated pallet costs.

PROGRAMMATICS

A brief but conservative analysis was made of the potential cost savings to be realized by the development of the six special emphasis items described above. In each case, the comparison was made against the current approach, an alternative item of MMSE, or custom procurement as applicable. Where no alternative MMSE item is feasible, the cost difference can be very dramatic as in the case of the spin-up mechanisms.

The results of this analysis are summarized in Table 2.

Table 2. Preliminary STS/MMSE Savings Estimate

ITEM	10-YEAR TOTAL COST SAVINGS
STS/NEW MMSE (6 SPECIAL EMPHASIS ITEMS)	$ 207 M *
STS MULTIPLE LAUNCHES VS. THOR-DELTA LAUNCHES (ORBITER COSTS AT $16.8M-$10.5M; THOR-DELTA AT $10M)	200 - 275 M
TOTAL POTENTIAL SAVINGS WITH STS/MMSE	407 - 475 M

*As opposed to present plans or other MMSE approaches/concepts

Relative timing for these six is seen in Figure 23. FY '76 study requirements and FY '77 hardware procurements are particularly notable.

CONCLUSIONS

1. The six special emphasis items show promise of improved payload accommodation with greatly reduced costs.

2. Two items need FY '77 procurements starts: PMDM, Spin-up Mechanisms.

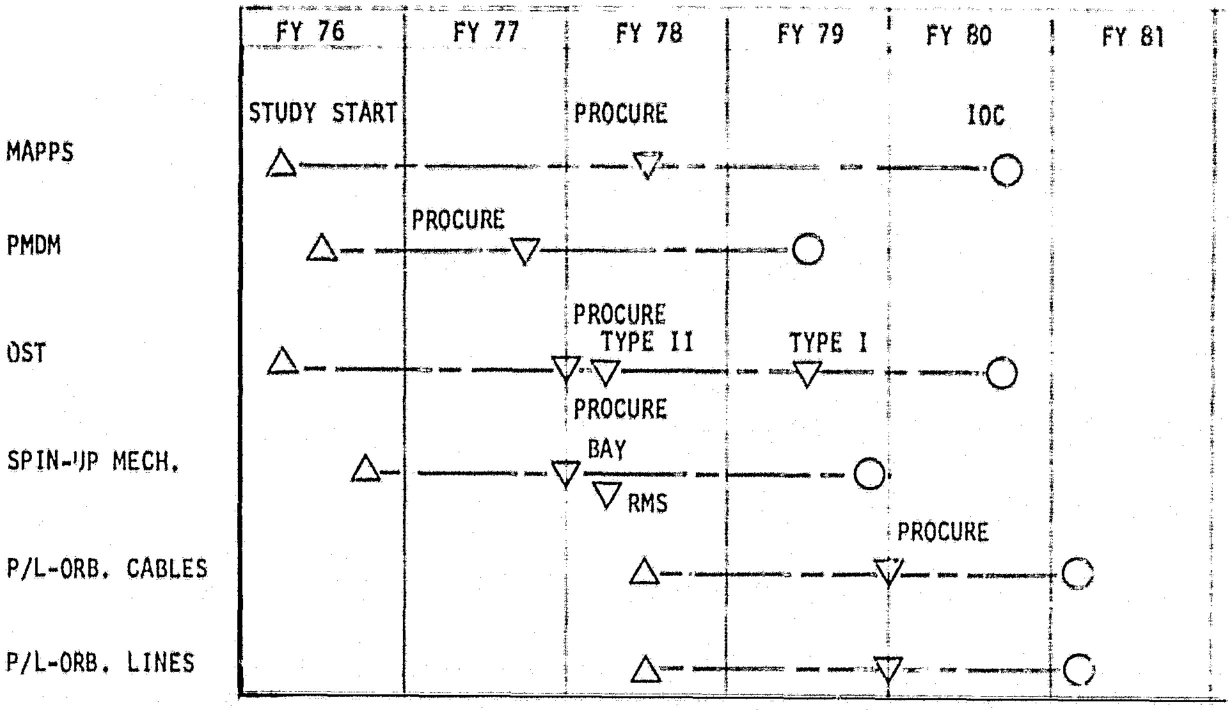


Figure 23. Summary of Timing for Recommended STS/MMSE Procurements

3. All but the fluid and electric lines require 1976 definition studies to prepare for subsequent procurement steps.

4. Provision for launching of small spinning satellites and Thor-Delta payloads in multiples is a Shuttle capability which should be exploited.

5. The cost-saving potential of these STS/MMSE items is well worth serious consideration in NASA planning. The funding of follow-on study for additional items appears warranted.

RECOMMENDATIONS

1. NASA should plan for the development of these six cost-effective STS/MMSE items.

2. NASA should consider 1976 funding of concept refinement studies for the STS/MMSE items to be developed.

3. NASA should provide for follow-on study effort on additional attractive items of STS/MMSE (as described in the Final Briefing).

4. NASA should consider placing the payload interface for electrical and fluid connections at the payload rather than at designated Orbiter points to facilitate commonality and integration.

5. NASA should seriously consider Shuttle launching of spinning upper stages in future mission capture analyses.